Response to Referee #4:

The authors would like to thank you for the constructive and thoughtful comments. We have addressed all your suggestions, leading to a much improved and complete manuscript. The following comments are addressed in the sequence as they were asked. We also respond to each point and clarify the corresponding changes adopted in the revised manuscript. The original comments are copied from the report with a **bolded font in black**, and our answers are in blue. Manuscript changes are in ***bold italic***.

Thank you again for your time and effort in reviewing our manuscript.

Yours sincerely

Baoqing Zhang (on behalf of all co-authors)

Reviewer #4

Overall comments

This manuscript developed a new global monthly drought index dataset with multi-types and multi-scales, SZIsnow. The drought index SZIsnow incorporates different physical water–energy processes with snow process. The dataset also was comprehensively evaluated by different drought types, different spatial scales. The drought index SZIsnow and SZI are compared in different regions.

The dataset can serve as a valuable resource for drought studies. The paper is scientifically sounding. The topic well fits the scope of this special issue. The manuscript is well written and logically organized and the dataset was easy to access. However, some concerns still need to be addressed and make it clearer for the readers before publication. Below are my several comments.

Reply: We appreciate the reviewer's comments on our work.

General Comments

1. The title used "standardized moisture anomaly index", however, "drought index" is used more in the text. Need to consider a better title to attract the interest of the potential data users.

Reply: We thank the reviewer for this excellent comment. The title will be changed to "***A global drought dataset of standardized moisture anomaly index incorporating snow dynamics (SZI$_{snow}$) from 1948 to 2010***" in the revised manuscript.

2. The abstract does not show the spatial resolution of your dataset. It is an essential parameter for reader and data user.

Reply: We cannot agree more with this comment. The spatial resolution of a dataset is an essential parameter for readers and data users. The spatial resolution of our proposed dataset is 0.25 degrees. This content will be added in the revised manuscript as follows:

Here, we present a global monthly drought dataset with a spatial resolution of 0.25° from 1948 to 2010 based on a multitype and multiscalar drought index, the standardized moisture anomaly index incorporating snow dynamics (SZI_{snow}), driven by systematic fields from an advanced data assimilation system.

3. In the Line 20, “Our results also show that the SZIsnow dataset successfully captured the largescale drought events that occurred across the world; there were 525 drought events with an area larger than 500,000 km^2 globally during the study period, of which nearly 70% had a duration longer than 6 months.” What is the accuracy rate of this product? How to evaluate this more reasonable? The product capture all the drought events? Is its capture rate 100%?

Reply: We thank the reviewer for this valuable comment. We recognize that the proposed product can not capture all the largescale drought events, and the capture rate is not 100%. The accuracy of drought assessment is a challenge for drought study, primarily because there did not exit an indicator to quantify drought directly. The lack of long-term observation is also the main reason for the difficulty of drought assessment. In addition, incomplete model structure, forcing data biases, and biases in parameter estimation in the forcing dataset (GLDAS-2) of the SZI_{snow} can lead to the inaccuracy of our results. Furthermore, the clustering algorithm of the SAD method allows for the merging of two or more sub-droughts into a drought. Although the smooth and continuous movement of the drought clusters hints at some common underlying mechanisms, it is sometimes difficult to interpret sub-droughts as a single event due to likely different forcing mechanisms behind them. From the above considerations, it is hard to give an accurate rate of the captured droughts.

To the best of the authors’ knowledge, the reasonable approach for evaluating our results is the comparison with the published paper in the science community. As shown in Section 4.3.2, we compared our captured events with those documented by other studies for each continent. Although these documented drought events were identified based on different drought indices, these comparisons indicate that our captured drought events are broadly aligned with findings from previous research. For example, Sheffield et al. (2009) pointed out that there have been 296 droughts greater than 500,000 km^2 globally from 1950 to 2000, with a dataset of soil moisture from simulations using the variable infiltration capacity model. This number is 311 in our result during the same period.

We recognize that the sentence in Line 20 is not an appropriate description of our results. Therefore, following the comment, this sentence will be corrected in the revised manuscript as follow:

Our results also indicate that the SZI_{snow} dataset can be employed to capture the largescale drought events that occurred across the world. Our analysis shows there were 525 drought events with an area larger than 500,000 km^2 globally during the study period, of which nearly 70% had a duration longer than 6 months.

4. In the Figure 1. I did not see the description of scPDSI in the manuscript.

Reply: As it is known, the self-calibrated PDSI (scPDSI) is developed based on the original PDSI and accounts for all the constants contained in PDSI. The scPDSI includes a methodology in which the constants are calculated dynamically based upon the characteristics present at each station location. Thus, the scPDSI can generate more representative model constants at temporal and spatial scales. In Figure 1, as the methodology is not significantly different from PDSI, it has the same issues as the PDSI in terms of the fixed temporal scale and poor performance over snow-covered areas. Therefore, we did not mention scPDSI in the manuscript.

Following the comment, we will add the below content in the revised manuscript:

In addition, the self-calibrated PDSI (scPDSI) can compute dynamically the constants in PSDI on the basis of the characteristics at each interested location, producing more representative model constants. However, the scPDSI has the same issues as the PDSI in terms of the temporal scale and performance over snow-covered areas.

5. I suggest adding the description of the advantages of the SZIsnow in the figure 1.

Reply: Following the comment, we will add the description of the advantages of the SZI_{snow} in Figure 1 of the revised manuscript:

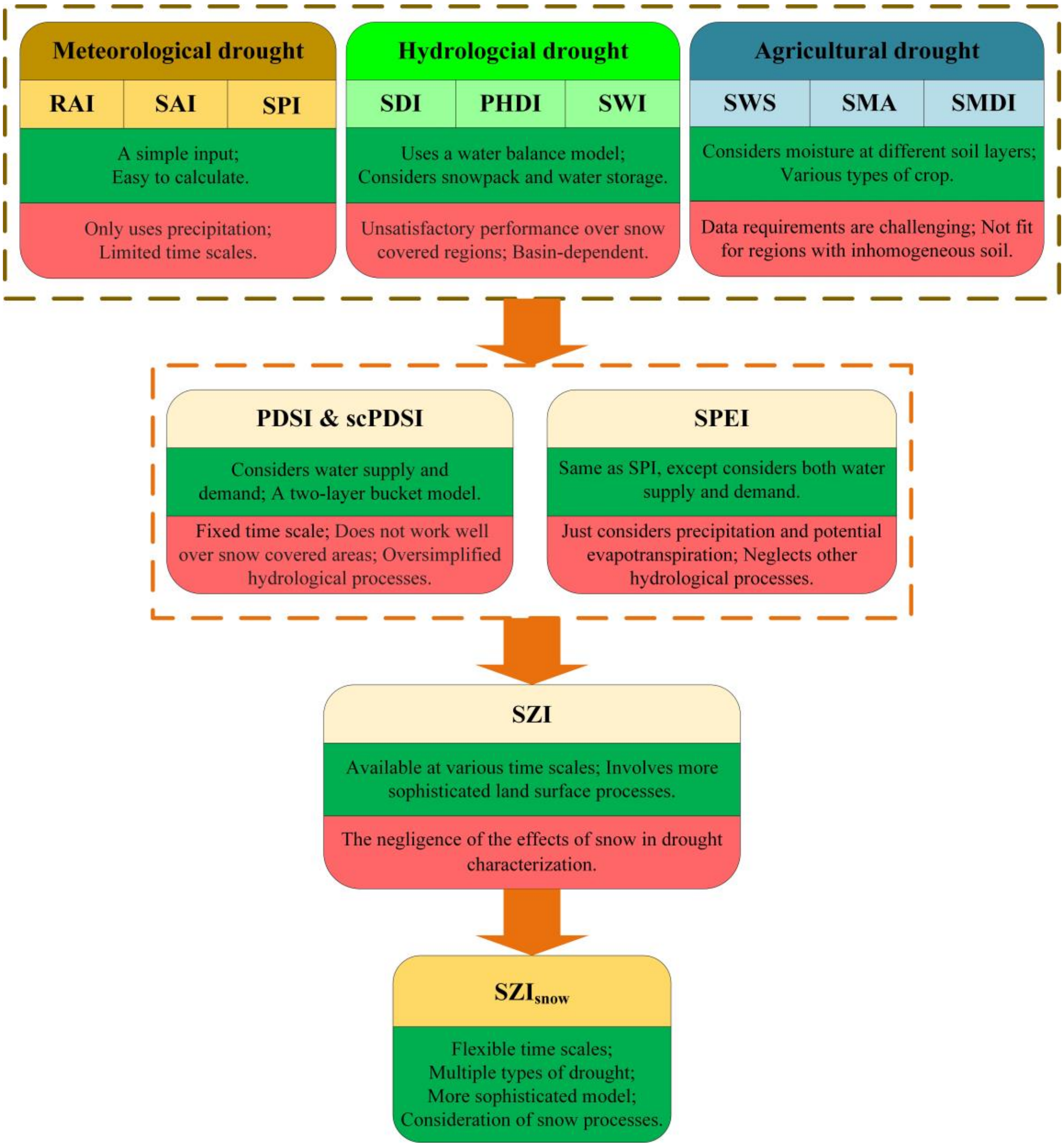

Figure 1. Development path of the SZI_{snow}. Dark green boxes denote the strengths of each drought index, while pink boxes denote the weaknesses of each drought index. The top row shows indices that can only account for one type of drought, with three indices listed for each type of drought. The second row shows indices that can account for multiple types of drought. Full names of the listed indices are shown in Table S1.

6. The GLDAS-2 data provide the variables to calculate the SZIsnow from 1948-2010. GLDAS-2.1 is one of two components of the GLDAS Version 2 (GLDAS-2) dataset, from 2000 to present. Is it possible to use GLDAS-2.1 to extend the time coverage of the product?

Reply: We thank the reviewer for this valuable suggestion. The time coverage of a drought index product is essential for drought study. The GLDAS-2.0 and GLDAS-2.1 are two components of the GLDAS Version 2 dataset (GLDAS-2). Although the GLDAS-2.0 is analogous to GLDAS-2.1, there are some differences in their meteorological forcing datasets. Thus, the performance of these two components might be different for a specific region. For example, a previous study found that different performances of GLDAS2.0 and GLDAS2.1 exists in runoff simulations over the Tibetan Plateau, which may be due to their different uncertainty in the forcing data (Qi et al., 2018). Moreover, the moisture anomaly (Z_{snow}) in SZI_{snow} can be aggregated at different temporal scales, causing the former months have influences on the latter months. An abrupt jump can be found in the time series of SZI_{snow} when we connect these two different forcing datasets, which will inevitably introduce systematic bias in the SZI_{snow}. Based on the above considerations, we temporarily did not extend the time coverage of the SZI_{snow} dataset using the GLDAS-2.1 product. In further work, this suggestion will be taken full account. We will appraise these two components and develop an approach to balance their differences, extending the time coverage of the SZI_{snow} dataset.

Qi, W., Liu, J., & Chen, D. (2018), Evaluations and Improvements of GLDAS2.0 and GLDAS2.1 Forcing Data's Applicability for Basin Scale Hydrological Simulations in the Tibetan Plateau, *Journal of Geophysical Research: Atmospheres*, 123(23), 13,128-113,148, https://doi.org/10.1029/2018JD029116.

7. Section 2.4 "Metrics for the SZIsnow evaluation" is not the data. It is an accuracy assessment method, not the data description. Is it more appropriate to move this part to the section 3.

Reply: Following the comment, we will move this section to Section 3 as Section 3.2 in the revised manuscript.

8. Line 164 "The prominent improvement of the SZIsnow is that it accounts for the influence of snowfall on hydrological processes, which was completely ignored in the SZI (Zhang et al., 2019; Zhang et al., 2015)."
Line 171 "Both the soil moisture storage and snow storage are considered as reservoirs in the SZIsnow, which is different from the SZI that solely considered the former."
This section is to discuss how to produce the SZIsnow. The difference between SZI and SZIsnow should be placed in the validation section

Reply: We should focus on how to produce the SZI_{snow}, instead of comparing the SZI and SZI_{snow}, since Section 3.1 discusses the derivation of the SZI_{snow}. We checked this section thoroughly to avoid a similar problem following the comment. All the similar sentences will be moved into the evaluation section to explain the different performances between the SZI and SZI_{snow}.

9. I suggest a procedure flowchart describing the production and validation of SZIsnow. It would be better that the advantages of the SZIsnow are mentioned in the figure. The flowchart can facilitate users to understand the dataset.

Reply: We cannot agree more with this comment. A procedure flowchart can facilitate users to understand the production and validation of the SZI_{snow} dataset.
Following the comment, we will add the below figure and its corresponding text in Section 3 of the revised manuscript:

We provide a procedure flowchart as shown in Figure 3 to show the production and validation of the SZI_{snow}. There are four steps for SZI_{snow} production: hydrologic accounting, climatic coefficients, water demand, and standardization. Hydrologic accounting is to calculate the monthly six components relevant to the local water budget; Climatic coefficients are the weighting factors of these components for the calculation of the local water demand; The local water demand in the SZI_{snow} is represented by the precipitation that is climatically appropriate for existing conditions (CAFEC, referred as $\widehat{P}_{snow}$); The last step is the standardization of the moisture anomaly (Z_{snow}), which is the difference between the actual precipitation (rainfall and snowfall). After achieving the global SZI_{snow} dataset, we not only validated SZI_{snow} for identifying different types of drought at basin scale, but also across different regions worldwide, especially snow-covered regions, at grid scale.

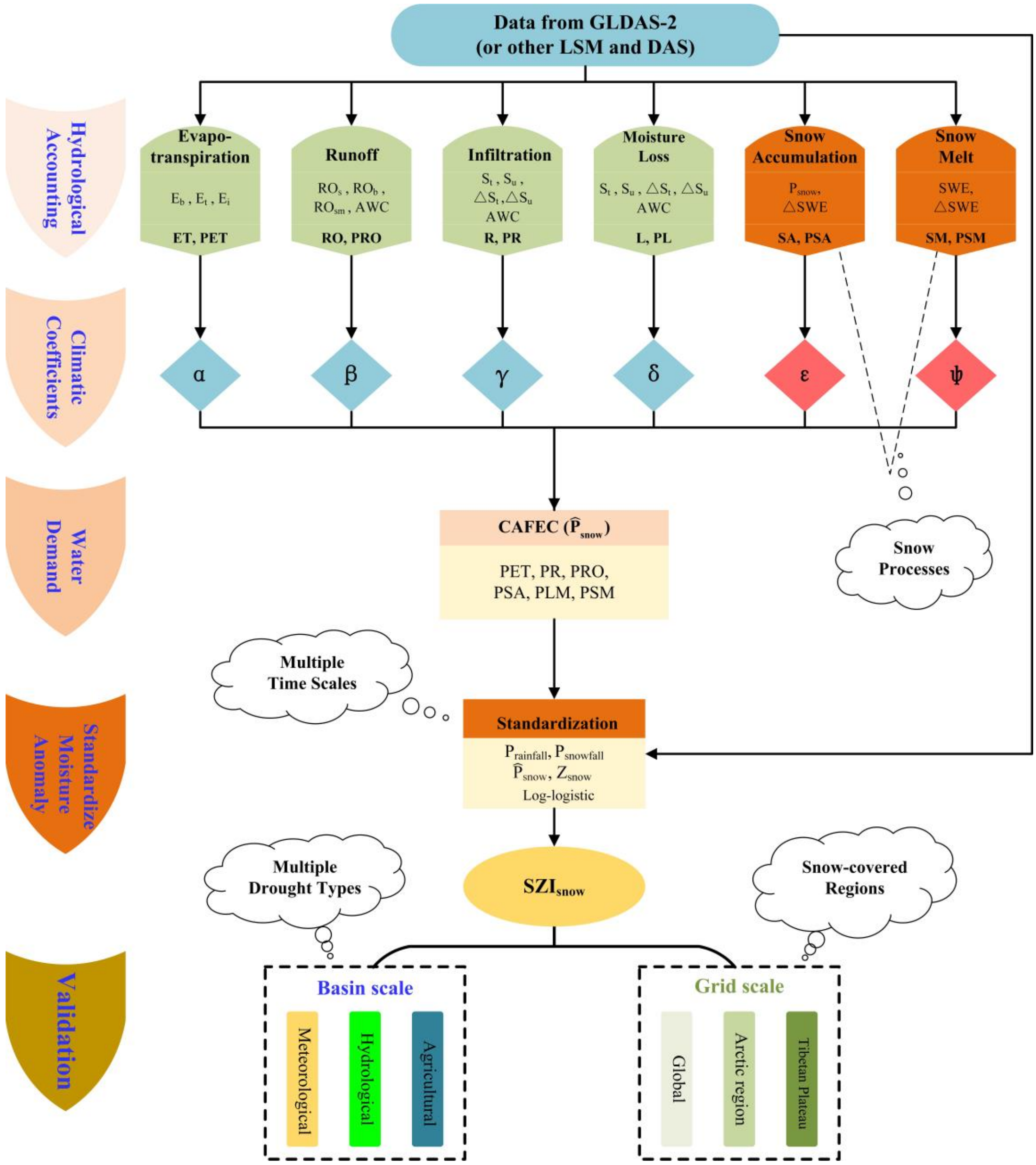

Figure 3. The procedure flowchart describing the production and validation of SZI_{snow}. Variables derive the SZI_{snow} from the GLDAS-2 (or other LSM and DAS). The production of SZI_{snow} includes four steps. The SZI_{snow} is validated at basin scale for three types of drought and at grid scale across different regions worldwide, respectively. The cloud-shape annotation shows the advantages of the SZI_{snow}.